

Mathematics Teacher TPACK Standards and Revising Teacher Preparation

Margaret Niess

Professor Emeritus of Mathematics Education, Science and Mathematics Education, Oregon State University, Corvallis, Oregon, 97331 USA niessm@onid.orst.edu

Abstract

What knowledge do teachers need for integrating appropriate digital technologies in teaching mathematics? An overarching construct called TPACK is proposed as the interconnection and intersection of knowledge among technology, pedagogy, and content and is referred to as the total knowledge package for teaching mathematics with technology. Five stages in the process of developing TPACK - *recognizing, accepting, adapting, exploring, and adapting* – describe the process of teachers’ learning to integrate technology. Teachers learn to teach mathematics from their own learning – K-12 mathematics - collegiate mathematics coursework, teacher preparation program, field experiences and professional development as they teach mathematics. The challenge is to identify appropriate experiences to guide this integration of technology in teaching mathematics in ways that develop TPACK. A framework for these experiences directs attention to emergent social and psychological perspectives.

Introduction

Technology tools like spreadsheets and calculators are typically viewed as computational tools for arithmetic computations. Yet, these tools are more accurately described as dynamic, algebraic reasoning tools. While many teachers fear that these tools rob students of “doing the math,” those who understand the tools’ affordances can revolutionize their students’ learning of mathematics. Rather than a rote-, algorithmic-, and answer-driven experience, students can be engaged in problem extension, asking “what if” questions of the problems, modeling different views of problems, working with open-ended problems, and encouraging question-posing to reveal the mathematics behind solutions to problems. Student can model mathematical systems rather than being restricted to multiple, repetitive symbolic manipulations for each variable change in a problem. In the process they investigate concepts of variables and covariation and are engaged in important mathematical processes, such as problem solving and mathematical modeling to analyze changes in various contexts (NCTM, 2000). The result is that they develop a more robust understanding of the content and processes of mathematics.

This vision of spreadsheets and calculators as algebraic reasoning tools rather than arithmetic computational tools, as tools to think mathematically, and as tools to learn mathematics suggests a significantly different mathematics curriculum and instruction than evidenced in the previous century. The problem is that today’s teachers learned mathematics in the past and typically view that mathematics must be learned the way they learned. In their teacher preparation programs, they developed general pedagogical methods and strategies with little attention to teaching mathematics with digital technologies. They may have had a technology course focused on the affordances and constraints of the technologies but little if any focus was on the integration of the technologies in teaching and learning mathematics. What happens when they enter the classroom to teach mathematics? They are more apt to teach mathematics the way they learned it – without integrating digital technologies that afford new ways of thinking in mathematics, technologies with the potential for engaging students in higher order thinking and reasoning to support them in learning mathematics.

Technology, Pedagogy, and Content Knowledge (TPACK)

Shulman (1986) launched a new way of thinking about the knowledge teachers need for teaching with a construct that he called pedagogical content knowledge (PCK). This new way of thinking about teacher knowledge called for the integration of content knowledge (the knowledge previously considered the primary knowledge domain for teachers) and pedagogical knowledge (the knowledge about teaching and learning). The revolution was that a teacher’s success in teaching relied on the knowledge from the intersection of these two knowledge bases. PCK was

described as the way of representing and formulating subject matter knowledge that makes those ideas comprehensible to learners.

This PCK lens redirected the efforts of educational researchers investigating the knowledge that teachers needed for teaching with technology. Earle (2002) explains why teachers' knowledge is seen as the key variable in teaching with technology:

Integrating technology is not about technology – it is primarily about content and effective instructional practices. Technology involves the tools with which we deliver content and implement practices in better ways. Its focus must be on curriculum and learning. Integration is defined not by the amount or type of technology used, but by how and why it is used. (p. 8)

This research direction ushered the description of an overarching knowledge construct as the interconnection and intersection of Technology, Pedagogy And Content Knowledge, called TPACK, the total knowledge package for teaching subject matter content with technology (Margerum-Leys & Marx, 2002; Mishra & Koehler, 2006; Niess, 2005; Pierson, 2001). Basically, these researchers defined TPACK as the knowledge that teachers need to teach with and about technology in their assigned subject areas and grade levels. The vision of TPACK has developed to the point that the American Association of Colleges of Teacher Education directed a collaboration of multiple TPACK authors in *The Handbook of Technological Pedagogical Content Knowledge for Educators* (Silverman, 2008).

Developing a Mathematics TPACK

What does TPACK knowledge mean for mathematics teachers? Niess (2005) adapted Grossman's (1989, 1990) four components of PCK to describe teachers' knowledge of incorporating technology in teaching mathematics as the knowledge and beliefs teachers demonstrate that are consistent with:

- An overarching conception about the purposes for incorporating technology in teaching mathematics;
- Knowledge of students' understandings, thinking, and learning of mathematics with technology;
- Knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics;
- Knowledge of instructional strategies and representations for teaching and learning mathematics with technologies.

Do teachers either have or not have TPACK? Niess, Sadri, and Lee (2007) proposed a developmental model for TPACK based on Rogers' (1995) five-stage process by which a person makes a decision to adopt or reject a new innovation. Over a four-year period, Niess, et al. observed teachers as they learned about spreadsheets and integrating spreadsheets as learning tools in their mathematics classrooms. Analysis of these observations described teachers at five stages:

1. *Recognizing* (knowledge) where teachers are able to use the technology and recognize the alignment of the technology with mathematics content, yet are not willing to integrate the technology in teaching mathematics in their classrooms.
2. *Accepting* (persuasion) where teachers may attempt to engage their students in learning mathematics with an appropriate technology as part of the process of determining if they have a favorable or unfavorable disposition toward incorporating the technology in their classrooms.
3. *Adapting* (decision) where teachers engage their students in activities in teaching and learning mathematics with an appropriate technology.
4. *Exploring* (implementation) where teachers actively integrate teaching and learning of mathematics with an appropriate technology.
5. *Advancing* (confirmation) where teachers evaluate the results of the decision to integrate teaching and learning mathematics with an appropriate technology.

An important consideration in these levels is that teachers may or may not traverse linearly through them; they may traverse through the early levels again for new and emerging technologies as they consider their usefulness in teaching mathematics. Each TPACK level was

then expanded using the lens of the four conceptions of the knowledge and beliefs teachers demonstrate in TPACK (Niess, 2007).

The Association of Mathematics Teacher Educator’s (AMTE) Technology Committee then developed a visual description of the TPACK levels (see Figure 1). On the left side, the figure highlights PCK as the intersection of pedagogy and content. As knowledge of technology intersects with pedagogical and content knowledge, the teachers’ knowledge base emerges as the knowledge described as TPACK – where teachers actively engage in guiding student learning of mathematics with technologies.

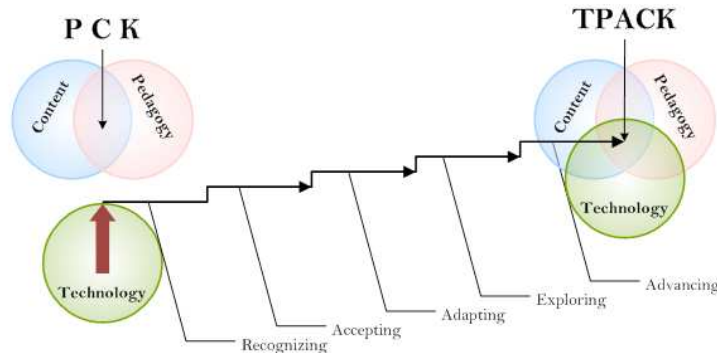


Figure 1. Teacher knowledge as their thinking and understanding merge toward TPACK.

Preparing Mathematics Teachers to Develop TPACK

Teachers’ knowledge for teaching mathematics is a construction that emerges from their early mathematical learning experiences, collegiate mathematical learning, teacher preparation programs, and professional development experiences as they are actively engaged in teaching mathematics. Many digital technologies (calculators, spreadsheets, applets of virtual manipulatives, dynamic geometry tools, and computer algebra systems) offer a broad spectrum of mathematical capabilities. Even more technologies are emerging and becoming accessible in schools for students in learning mathematics. The key challenge is for mathematics teacher educators to design, implement, and evaluate new teacher preparation programs that provide experiences that support the development of the knowledge, skills, and dispositions in TPACK for teaching mathematics.

Table 1. A Framework for Learning to Teach with Technology

Professional Expertise	Social Perspective	Psychological Perspective
<i>Professional Identity</i>	Pedagogical Social Norms	Pre-service teacher’s beliefs about their own role, others' role and the general nature of technology
<i>Technology Specific Pedagogy</i>	Norms of Pedagogical Reasoning about Technology	Pre-service teacher’s overarching conception of teaching mathematics with technology
		Pre-service teacher’s knowledge of student understandings, thinking, and learning mathematics with technology
<i>Content Knowledge</i>	Classroom Pedagogical Practices With Technology	Pre-service teacher’s knowledge of instructional strategies and representations for teaching with technologies
		Pre-service teacher’s knowledge of curriculum and curricular materials

How mathematics teachers learn, with whom they learn, and the context in which they learn are

fundamental to *what* they learn (Greeno et al., 1996). Harrington (2008) notes that learning to teach mathematics with technology must be viewed from both social and psychological perspectives. She describes TPACK from an emergent perspective that takes into account what is known about TPACK from the psychological perspective focused on the four components of TPACK (Niess, 2005) and includes what needs to be known from a social perspective as shown in Table 1. The framework guides the educational experiences for teachers to teach mathematics where they gain professional identity, technology specific pedagogy and content knowledge.

Mathematics pre-service teachers' development of TPACK depends on many factors, including experiences that use appropriate technologies as they learn mathematics at the collegiate level. Their content learning environments must go beyond simply expecting them to mimic experiences modeled as they learned mathematics. From social and psychological perspectives, these pre-service teachers need to engage in more experiences than simply learning the mathematics; they need to engage in analyzing (1) the affordances/constraints of using a certain technology to teach particular mathematics content, (2) teaching the content changes as a result of using the technology, (3) creating appropriate assessments that include the use of technology, (4) posing questions that enhance and extend students' learning of mathematics while using technology, and (5) developing their knowledge about technologies that exist for teaching and learning specific mathematics concepts. Not all collegiate mathematics content faculties have an advanced level of TPACK. Yet, current thinking suggests that they need to guide pre-service teachers' thinking about what is taught with the technology, why the technology is chosen for the particular mathematics concept, the affordances and constraints of using the technology to teach the particular mathematics concept, why certain questions are posed in scaffolding instruction, and why the assessment is chosen.

Teacher education courses, in particular the mathematics methods courses, have potential for impacting pre-service teachers development of mathematics TPACK. As in the recognition of the importance of PCK for teacher knowledge, teacher preparation programs must integrate learning and teaching with and about technology from the content – the mathematics- and the pedagogy perspectives. Pre-service programs need to engage future teachers in aligning concepts and skills with appropriate technologies with national/state content standards, forcing them to reflect on how and why the technology should be used in mathematics instruction (Niess, 2005). They need to learn how to reason pedagogically about technologies as well as in their practices in a mathematics classroom. Developing these habits of mind in social situations are critical if teachers are to develop the psychological perspectives of professional identity, technology specific, pedagogy and content knowledge. Further research is needed to develop a model of mathematics teacher education that takes into account structures of the coursework, approaches to technology education, and activities pre-service teachers experience.

Field experiences are essential teacher preparation experience, providing authentic contexts for thinking about, designing, implementing, and assessing the impact of integrating technologies in learning mathematics. As an alternative, Bullough et al. (2003) found that pre-service teachers were able to synthesize their coursework and field experiences more effectively and their relationships with the cooperating teacher were more collaborative in nature when they were placed in classrooms with peers. Harrington (2008) captured pre-service teachers TPACK development in a collaborative field experience where they: (1) offered ideas during team lesson planning, (2) justified their thinking to peers, instructors and cooperating teachers, and (3) when making choices during their own teaching. Taken together these opportunities define *patterns of participation* across the learning contexts of peer interaction, coursework and field experiences as they learn to teach with technology (Peressini et al., 2004).

Pre-service teachers need multiple opportunities and contexts in which to develop their TPACK and this development takes time. Their development is influenced by past experiences and formal ideas begin to surface during their coursework. Formal ideas are enacted as pre-service teachers begin their field experiences. Important research questions need to be framed and studied to guide

the development of programs to provide pre-service and in-service teachers with opportunities to develop and display their TPACK. What are the situations that facilitate this development? What happens beyond the traditional models of teacher preparation? Research is definitely needed.

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